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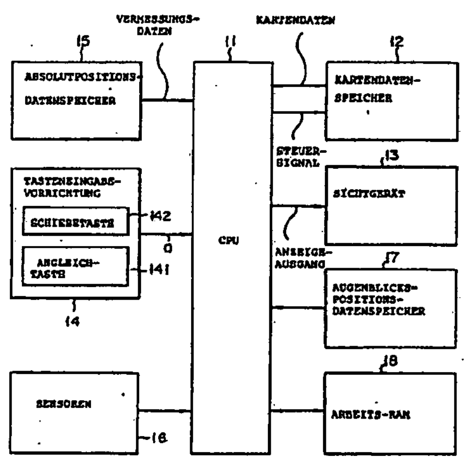

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Geometric Centroid

The center of mass of a two-dimensional planar lamina or a three-dimensional solid. The mass of a lamina with surface density function $\sigma(x, y)$ is

$$M = \iint \sigma(x, y)\, dA, \quad (1)$$

and the coordinates of the centroid (also called the center of gravity) are

$$\bar{x} = \frac{\iint x\, \sigma(x, y)\, dA}{M} \quad (2)$$

$$\bar{y} = \frac{\iint y\, \sigma(x, y)\, dA}{M}. \quad (3)$$

The centroid of a lamina is the point on which it would balance when placed on a needle. The centroid of a solid is the point on which the solid would "balance."

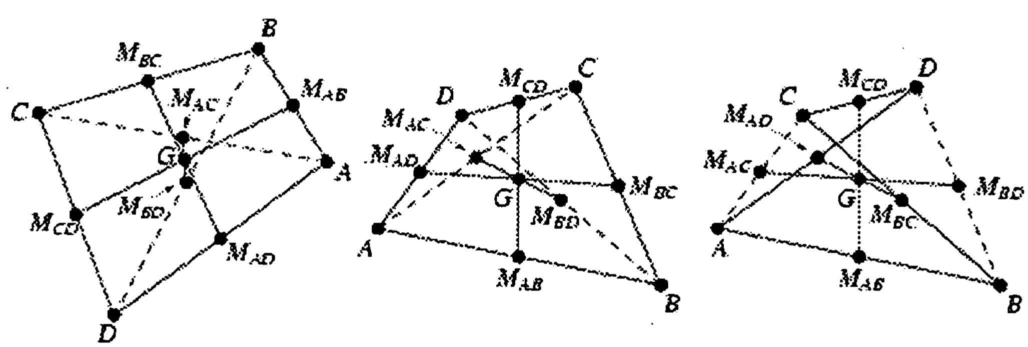
The centroid of a set of n point masses m_i located at positions $\mathbf{x}_i$ is

$$\bar{\mathbf{x}} = \frac{\sum_{i=1}^{n} m_i\, \mathbf{x}_i}{\sum_{i=1}^{n} m_i}, \quad (4)$$

which, if all masses are equal, simplifies to

$$\bar{\mathbf{x}} = \frac{\sum_{i=1}^{n} \mathbf{x}_i}{n}. \quad (5)$$

The centroid of n point masses also gives the location at which a school should be built in order to minimize the distance travelled by children from n cities, located at the positions of the masses, and with m_i equal to the number of students from city i (Steinhaus 1999, pp. 113-116).



The centroid of the vertices of a quadrilateral occurs at the point of intersection of

the bimedians (i.e., the lines $M_{AB} M_{CD}$ and $M_{AD} M_{BC}$ joining pairs of opposite midpoints) (Honsberger 1995, pp. 36-37). In addition, it is the midpoint of the line $M_{AC} M_{BD}$ connecting the midpoints of the diagonals AC and BD (Honsberger 1995, pp. 39-40).

Given an arbitrary hexagon, connecting the centroids of each consecutive three sides gives the so-called centroid hexagon, a hexagon with equal and parallel sides (Wells 1991).

The centroid of a semicircle of radius R is given by

$$\bar{x} = \frac{2R}{\pi}. \tag{6}$$

The centroids of several common laminas bounded by the following curves along the nonsymmetrical axis are summarized in the following table.

lamina	$\bar{y}$
circular segment	$\frac{4R\sin^3\left(\frac{1}{2}\theta\right)}{3(\theta-\sin\theta)}$
parabolic segment	$\frac{2}{5}h$
semicircle	$\frac{4R}{3\pi}$

In three dimensions, the mass of a solid with density function $\rho(x, y, z)$ is

$$M = \iiint \rho(x, y, z)\, dV, \tag{7}$$

and the coordinates of the center of mass are

$$\bar{x} = \frac{\iiint x\,\rho(x, y, z)\, dV}{M} \tag{8}$$

$$\bar{y} = \frac{\iiint y\,\rho(x, y, z)\, dV}{M} \tag{9}$$

$$\bar{z} = \frac{\iiint z\,\rho(x, y, z)\, dV}{M}. \tag{10}$$

Figure	$\bar{z}$
cone	$\frac{1}{4}h$
conical frustum	$\frac{h(R_1^2+2R_1R_2+3R_2^2)}{4(R_1^2+R_1R_2+R_2^2)}$
hemisphere	$\frac{3}{8}R$
paraboloid	$\frac{2}{3}h$
pyramid	$\frac{1}{4}h$

SEE ALSO: Centroid Hexagon, Pappus's Centroid Theorem. [Pages Linking Here]

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Centroid Of An Area

The centroid of an area is similar to the center of mass of a body. Calculating the centroid involves only the geometrical shape of the area. The center of gravity will equal the centroid if the body is homogenous i.e. constant density. Integration forr for calculating the Centroid are:

$$C_x = \frac{\int x dA}{A} \qquad C_y = \frac{\int y dA}{A} \qquad A = \int f(x)dx$$

When calculating the centroid of a complex shape. Divide the shape up into a combination of known shapes. Then use the the following formula:

$$C_x = \frac{\sum_n A_n C_{x_n}}{\sum A_n} \qquad C_y = \frac{\sum_n A_n C_{y_n}}{\sum A_n}$$

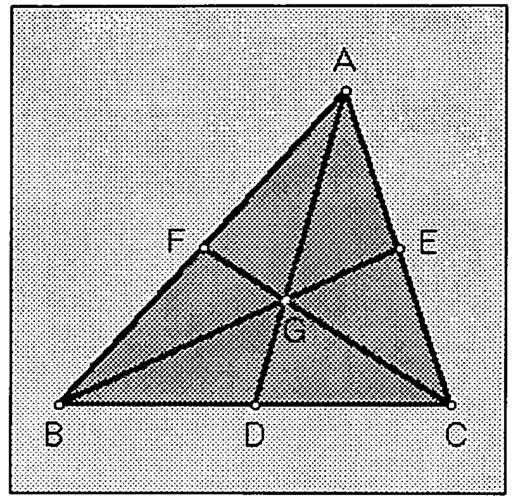
The distance from the y-axis to the centroid is C_x

The distance from the x-axis to the centroid is C_y

The coordinates of the centroid are (C_x, C_y)

The centroid location of many common shapes is known. The Properties of Areas pa includes the Centroid Location, Area, Area Moments of Inertia, Area Polar Moments Inertia, & Area Radius of Gyration for many common shapes.

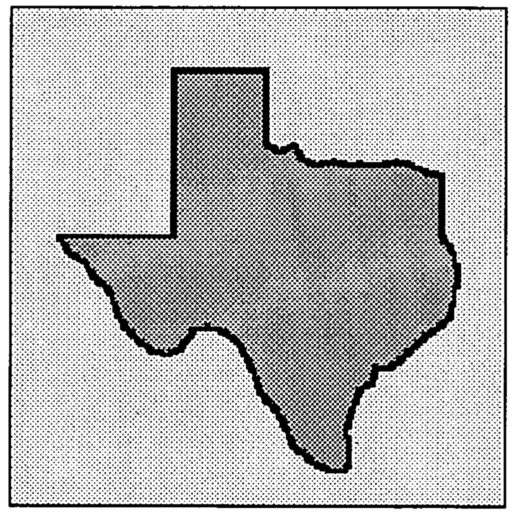
CENTROID



In the plane of any triangle ABC, let

D = midpoint of side BC,
E = midpoint of side CA,
F = midpoint of side AB.

As you see in the sketch, the lines AD, BE, CF all come together in one point, called the *centroid* of triangle ABC. There are many other points that are called triangle centers, but unlike most of them, "centroid" works on arbitrary shapes.



For example, you can form the centroid (also called *center of mass* or *center of gravity*) of Texas.

Cut out a map of Texas from cardboard, hang it by a string, and draw a vertical line from the point of suspension down across the cardboard.

Then remove the string, rotate Texas a few degrees, and repeat the procedure. Your two lines will meet right at the centroid. (It's not far from the capital, Austin.)

One of the many interesting properties of the centroid of a triangle is that it is the unique point P for which the three triangles BCP, CAP, ABP all have the same area.

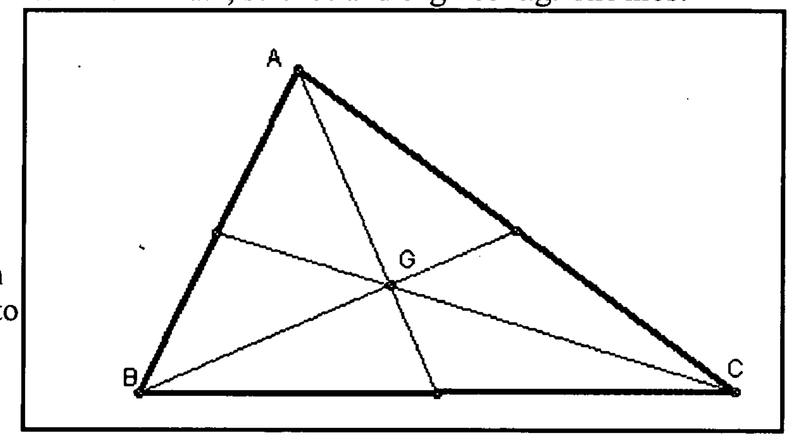
Triangle Centers
Clark Kimberling Home Page

Centroid

Back to MathWords

The centroid of a body is the center of its mass (or masses), the point at which it would be stable, or balance, under the influence of gravity. There are other names for the same point. It is also often called the **center of gravity** and the **geocenter** and barycenter.

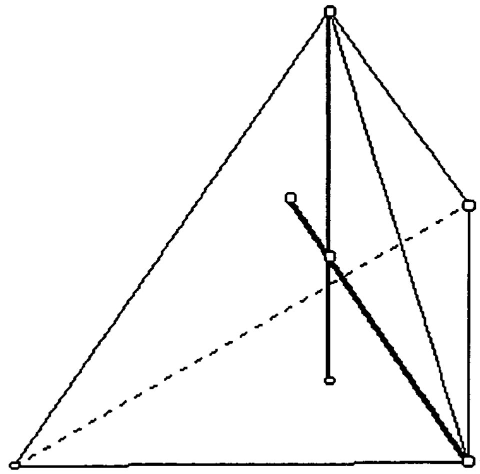
There are three common "centers of gravity" that are studied in math, science and engineering. The most common in math is the center of masses located at the vertices of a polygon. This is more common because the other two cases can be reduced to a variation of this approach. It is this case of point masses at the vertices that I mean when I use centroid or center of gravity in this note, unless otherwise stated. A second approach is to treat the area of the polygon as if it were a sheet of uiniform density. The third, and least common, approach is to represent the sides of the polygon as wire rods of uniform density.



Most students are first introduced to the terms above in reference to a point in a triangle. Since the center of masses at the vertices in a triangle give the same point as a uniform sheet, they are often confused about the various distinctions. The three centers of gravity are usually different points in other non-symmetric polygons. It is this point, the center of balance for the uniform sheet and also of point masses at the vertices, that is almost universally referenced as the **centroid** of a triangle.
The centroid of a triangle is a point at the intersection of the three medians of the triangle. One of the basic ideas known about the centroid is that it it divides the medians into a 2:1 ratio. The part of the median nearest the vertex is always twice as long as the part near the midpoint of the side. If the coordinates of the triangle are known, then the coordinates of the centroid are the averages of the coordinates of the vertices. If we call the three vertices A=(x1,y1); B=(x2,y2) and C=(x3,y3) then the coordinates of the geocenter would be

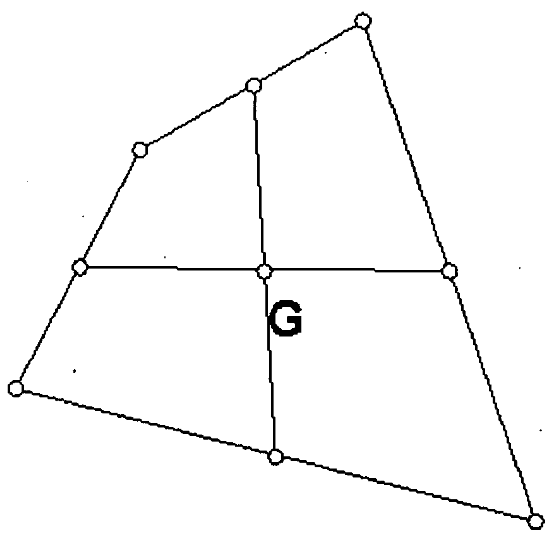
$$\left(\frac{x1+x2+x3}{3},\frac{y1+y2+y3}{3}\right)$$

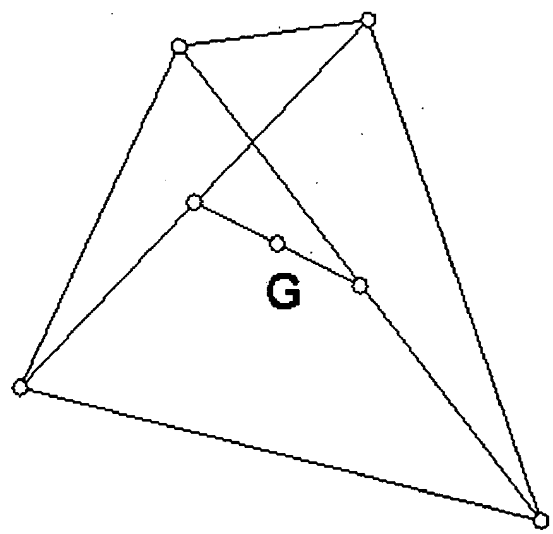
This is extendable to the centroid of a tetrahedron in three space. If we construct the centroids of each of the triangular faces and construct the "medial segment" from each vertex to the centroid of the opposite face, they will also intersect in a single point, the centroid of the tetrahedron. and the x,y,z coordinates of the centroid is the average of the corresponding coördinates of the four vertices. The centroid of a tetrahedron divides the medial segments into a 3:1 ratio.



If the midpoints of opposite pairs of edges of a tetrahedron are connected they will all intersect at the centroid also. Recently while rereading Great Moments in Mathematics before 1650 by Howard Eves I found that the extension above was called "Commandino's theorem". It is named for Federigo Commandino and was published in his *De Centro Gravitatus Solidorum* [On centers of gravity of solids] in 1565. Commandino translated many of the classic Greek mathematical texts and a quote from St Andrews web site says that Commandino "had the greatest influence of anybody in ensuring that the classic Greek mathematical texts survived by publishing his editions of them."

In a quadrilateral, the line joining the midpoints of two opposite sides is called a **bimedian**. The centroid of masses located at the vertices of a quadrilateral is also the intersection of the bimedians of a quadrilateral. Another property of the quadrilaterals centroid is that it is also the midpoint of the segment joining the midpoints of the diagonals.





The advantage of using the point mass approach to finding centers of gravity is that the other two common cases can be reduced to point masses of uneven weights very easily. To find centers of gravity of uniform density sheets, one can simply divide the polygon into non-overlapping triangles and treat the system as a set of point masses at the centroids of these triangles with a mass equal to the area of the triangle. To find the center of uniform rods along the perimeter of a polygon, replace each side with a point mass equal to the length of the line located at its midpoint. The center of gravity of uniform wire rods on the perimeter of a triangle is the Spieker point, which is the incenter of the medial triangle. Professor Kimberling has a page showing how to find the center of mass of any shape by a physical method.

A direct method of finding the center of gravity of a uniform density sheet in the shape of a quadrilateral was found by F. Wittenbauer (1857-1922). If the triesectors of each edge of the quadrilateral are found, and lines are

drawn through each pair of trisectors adjacent to a vertex, they form a parallelogram, **Wittenbauer's Parallelogram**. The center of the parallelogram is the center of gravity of the uniform sheet.

The word is based on the word center and the Greek suffix *oid* and means "center like". It probably is a relatively modern word, perhaps created after 1850.

centroid

(definition)

Definition: The center of gravity or center of mass of an object.

Author: PEB

More information

Clark Kimberling's pictorial example and physical method of finding the centroid of an plane object. A more analytical description and information about the word's origin.

Go to the Dictionary of Algorithms and Data Structures home page.

If you have suggestions, corrections, or comments, please get in touch with Paul E. Black (paul.black@nist.gov).

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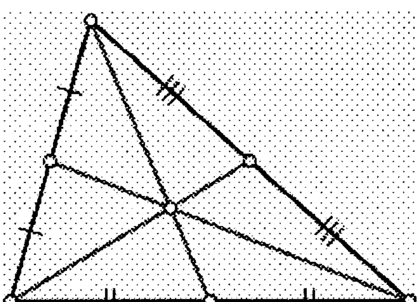
In geometry, the **centroid** or **barycenter** of an object *X* in *n*-dimensional space is the intersection of all hyperplanes that divide *X* into two parts of equal moment about the hyperplane. Informally, it is the "average" of all points of *X*.

In physics, the centroid can, under some circumstances, coincide with an object's center of mass and also with its center of gravity. In some cases this leads to the usage of those terms interchangingly. For a centroid to coincide with the center of mass, the object should have uniform density, or the matter's distribution through the object should have certain properties, such as symmetry. For a centroid to coincide with the center of gravity, the centroid must coincide with the object's center of mass and the object must be under the influence of a uniform gravitational field.

A concave figure might have a centroid that is outside the figure itself. The centroid of a crescent, for example, lies somewhere in the central void.



The **centroid** of a triangle is the point of intersection of its medians (the lines joining each vertex with the midpoint of the opposite side). This point is also the triangle's center of mass if the triangle is made from a uniform sheet of material.

See also

- Pappus's centroid theorem

External Links

- Characteristic Property of Centroid (*http://www.cut-the-knot.org/triangle/CharacteristicPropertyOfCentroid.shtml*)
- Barycentric Coordinates (*http://www.cut-the-knot.org/triangle/barycenter.shtml*)

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